REVISION OF THE AUSTRALIAN TERTIARY SPECIES ASCRIBED TO *LIMATULA* WOOD (MOLLUSCA, BIVALVIA)

by M. F. BUONAIUTO*

Summary

BUONAIUTO, M. F. (1977).—Revision of the Australian Tertiary species ascribed to *Limatula* Wood (Mollusca, Bivalvia). *Trans. R. Soc. S. Aust.* **101**(1), 21-33, 28 February, 1976.

Limatula crebresquamata Tate (Late Eocene-Miocene) and *Limatula jeffreysiana* Tate (Early Miocene) are revised. The Late Eocene *L. margaritata* sp. nov. and the Pliocene *L. ludbrookae* sp. nov. have hitherto been mistaken for *L. jeffreysiana*. The Early Pliocene *L. subnodulosa* Tate is shown to be a synonym of *Limea (Gemellima) austrina* Tate. A brief discussion and revision of the Tortachilla Limestone is given and a new procedure for S.E.M. photography is described.

Introduction

Hitherto only three fossil species of *Limatula* Wood were known or recognized in the Australian Tertiary: *L. jeffreysiana* (Tate), now known to be Early Miocene in age, the Late Oligocene-Early Miocene *L. crebresquamata* Tate, and the Early Pliocene *Limatula subnodulosa* Tate, here believed to be a worn specimen of *Limea* (*Gemellima*) *austrina* Tate. Observations made during a current revision of the Eocene Molluscan faunas have revealed that two specimens of the series of *L. jeffreysiana* borne on the tablet SAM T972 from Tate's collection, represent two other species: the Late Eocene *L. margaritata* sp. nov. (T972-M) and the Pliocene *L. ludbrookae* sp. nov. (T972-D).

The material here examined is in the Tate Collection and Mollusc Collection housed in the South Australian Museum (SAM), which remains the property of the Department of Geology and Mineralogy, University of Adelaide.

Optimal S.E.M. results were obtained by pretreating the specimens by exposure to osmiumtetraoxide vapour for twelve hours, followed by coating with carbon and gold-palladium. Carbon or silver dag or tragacanth glue did not influence the results, and problems of high charging were eliminated other than where there was imperfect specimen-stub connection or coating. It produced excellent resolution even of very rough surfaces at high magnifications, and represents an extreme simplification of Robertson's (1971) technique.

Systematic descriptions

CLASS	BIVALVIA Linné, 1758
SUBCLASS	PTERIOMORPHIA Beurlen, 1944
ORDER	PTERIOIDA Newell, 1965
SUBORDER	PTERIINA Newell, 1965
SUPER-FAMILY	LIMACEA Rafinesque, 1815
FAMILY	LIMIDAE Rafinesque, 1815
GENUS	*Limatula* Wood, 1839

Diagnosis. Shell small, oval, higher than long, inflated, without umbonal ridges; auricles small, subequal; margins not gaping; hinge edentulous; ornaments of primary radial riblets and secondary concentric costellae, more conspicuous on the dorsal and ventral regions; concentric ornaments can develop into primary in the anterior and posterior regions; median sulcus can occur (after Cox & Hertlein, 1969, p. N389).

Limatula margaritata sp. nov.

FIGS 1, 6-9

Derivation of name. From the Latin *margaritatus*, beaded, because of its beaded ribs.

Holotype. SAM P18343, figs 6-7, 9.

Type-formation. Tortachilla Limestone, Late Eocene.

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Type-locality. Maslin Bay, Willunga Sub-Basin, St Vincent Basin.

Material. 172 specimens (21 RV, 22 LV, 129 VV) generally very badly preserved; the topotype SAM T972-M from Tate's collection.

Description. Shell small, oval, higher than long, inflated, slightly inequilateral; umbo central, inflated with little protruding orthogyrate beaks. Margins: anterior and posterior subelliptical, winged; ventral very elliptical. Margin connections: postero-ventral imperceptible; antero-ventral rounded, angular. Auricles small, subequal, longer than high, with protruding ends. Longitudinal shell section convex with maximum at the posterior ridge. Regions: anterior flatter and steep; posterior convex and steep; dorsal and ventral more convex and steeper to the ventral margin. Commissure region crenulate. Cardinal area narrow and rather long, resilifer deep, hinge edentulous.

Ornament. About 40 radial triangular costae with narrow trapezoid trough-shaped interspaces, wider to the anterior and posterior regions. The costae fade to the auricles; marked concentric grooves separating concentric weak costellae; the costellae thicken to the auricles. Costa-costella intersections bear triangular beads. Auricles with concentric costellae and growth lines.

Observations. This form was included by Tate in *L. jeffreysiana* which is Miocene. A topotype is mounted on the tablet SAM T972 labelled *Limatula jeffreysiana* (Tate). Distinctive differences between the species are tabulated in the comparative synopsis in Table 1. The holotype, although rather juvenile, was chosen because it is the only specimen in a good state of preservation, and has a sure stratigraphic location.

Stratigraphic range. Tortachilla Limestone to Blanche Point Transitional Marls (lowermost member of Blanche Point Marls); Late Eocene.

Limatula jeffreysiana (Tate, 1885)

FIGS 1-5

1877 *Lima* (*Limatula*) *subauriculata* Tenison Woods, p. 113 (*non* Montfort). 1885a *Lima jeffreysiana* Tate, p. 208 (*nom. nud.*). 1885a *Lima subauriculata*: Tate, p. 213 (*non* Montfort). 1885b *Lima jeffreysiana* Tate, p. 230. 1886 *Lima* (*Limatula*) *jeffreysiana*: Tate, p. 119, pl. 4, fig. 8 (pars). 1896 *Limatula jeffreysiana*: Pritchard, p. 128. 1897 *Lima* (*Limatula*) *jeffreysiana*: Harris, p. 311. 1899 *Lima* (*Limatula*) *jeffreysiana*: Tate, p. 273. 1924 *Lima jeffreysiana: Marwick*, p. 323.

Material. 11 specimens (4 LV + 5 RV + 1 BV) generally well preserved. (SAM T972 A-C, E-L; Coll. Tate.)

Description. Like *L. margaritata*. Differs from it by greater height, less inflation, narrower ventral margin, by longer and narrow ears with more protruding ends.

Ornament. 34-37 triangular thin radial ribs, more spiny on the ventral region, with broad concave to flattened interspaces, narrower on the dorso-ventral region, broader to the anterior and posterior, where ribs fade to the auricles. Very fine growth lines; broadly interspaced concentric costellae, more marked in the anterior and posterior regions. Auricles with concentric costellae. Median radial sulcus shallow and observable only in younger specimens.

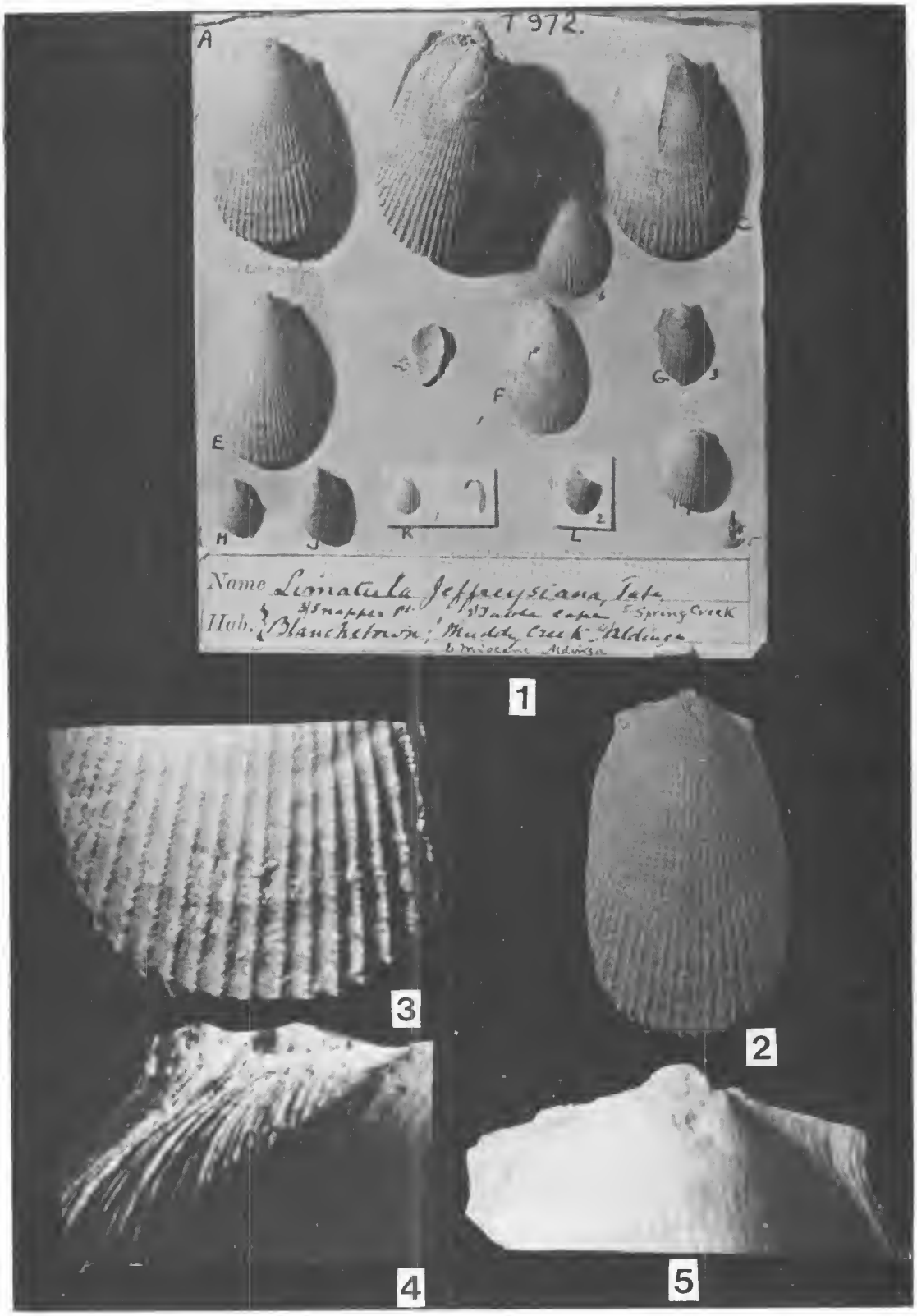
Observations. The tablet SAM T972 bears specimens of *L. jeffreysiana* (Tate), together with specimens here described as *L. margaritata* sp. nov. (T972-M) and *L. ludbrookae* sp. nov. (T972-D).

Tenison Woods referred the species to the living *L. subauriculata* (Montfort, *non* Montagu). Tate (1885a, 1885b) distinguished it as a new fossil species and remarked its close affinity with the living *L. strangei* Sowerby (MacPherson & Gabriel 1962, p. 308, fig. 3501; Cotton & Godfrey 1938, p. 108, fig. 97; this study, fig. 20-26). Later, Tate (1899) also referred to *L. jeffreysiana* a New Zealand fossil form, mistaken for the living *L. bullata* Born (Hutton 1873, p. 33). Marwick (1924, p. 323) separated the New Zealand form, that was later named by Finlay *L. maoria* (Finlay 1927, p. 454, figs 104-6). The holotype has not been located; it does not appear to be in the Tasmanian Museum, Hobart (Ludbrook 1967). The two specimens found in Tate's collection are both juveniles and one (T972-L) is broken. Hence, it is here considered inappropriate to choose one of them as neotype.

Distribution. Table Cape, Bass Basin (type); Muddy Creek, "Murray River" Snapper Point, Blanchetown, "Spring Creek". Other localities

Fig. 1. Tablet SAM T972 (Coll. Tate) bearing specimens of *L. jeffreysiana* (Tate). T972-D: a paratype of *L. ludbrookae* sp. nov.; T972-M: a topotype of *L. margaritata* sp. nov. (x 1.1).

Figs 2-5. *Limatula jeffreysiana* (Tate), plesiotype (SAM T972-A), LV, Muddy Creek; (2) dorsal view (x 2); (3) ornaments, particular from ventral region (x 4); (4) anterior auricle (x 9.3); (5) umbonal region and posterior auricle (x 3.8).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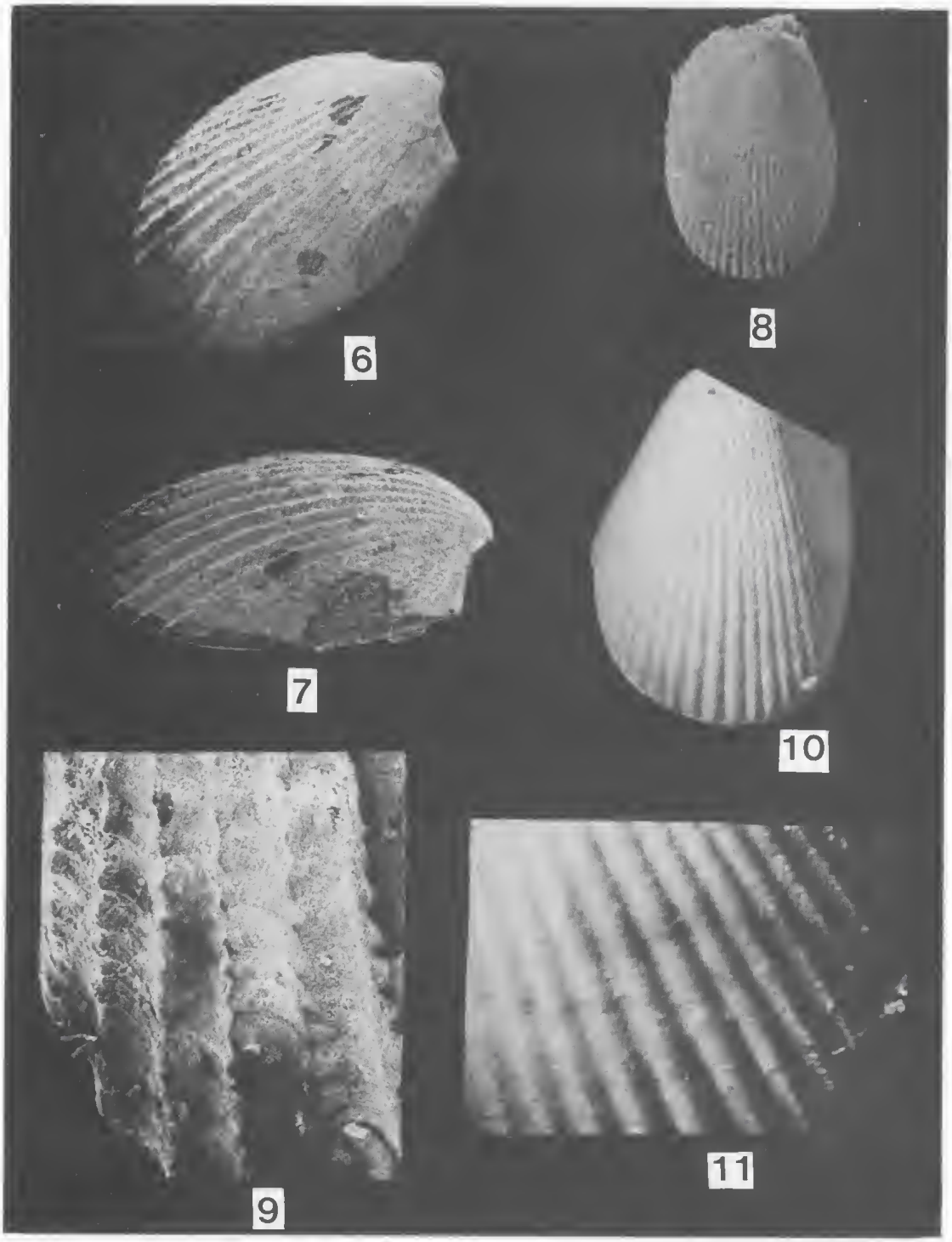
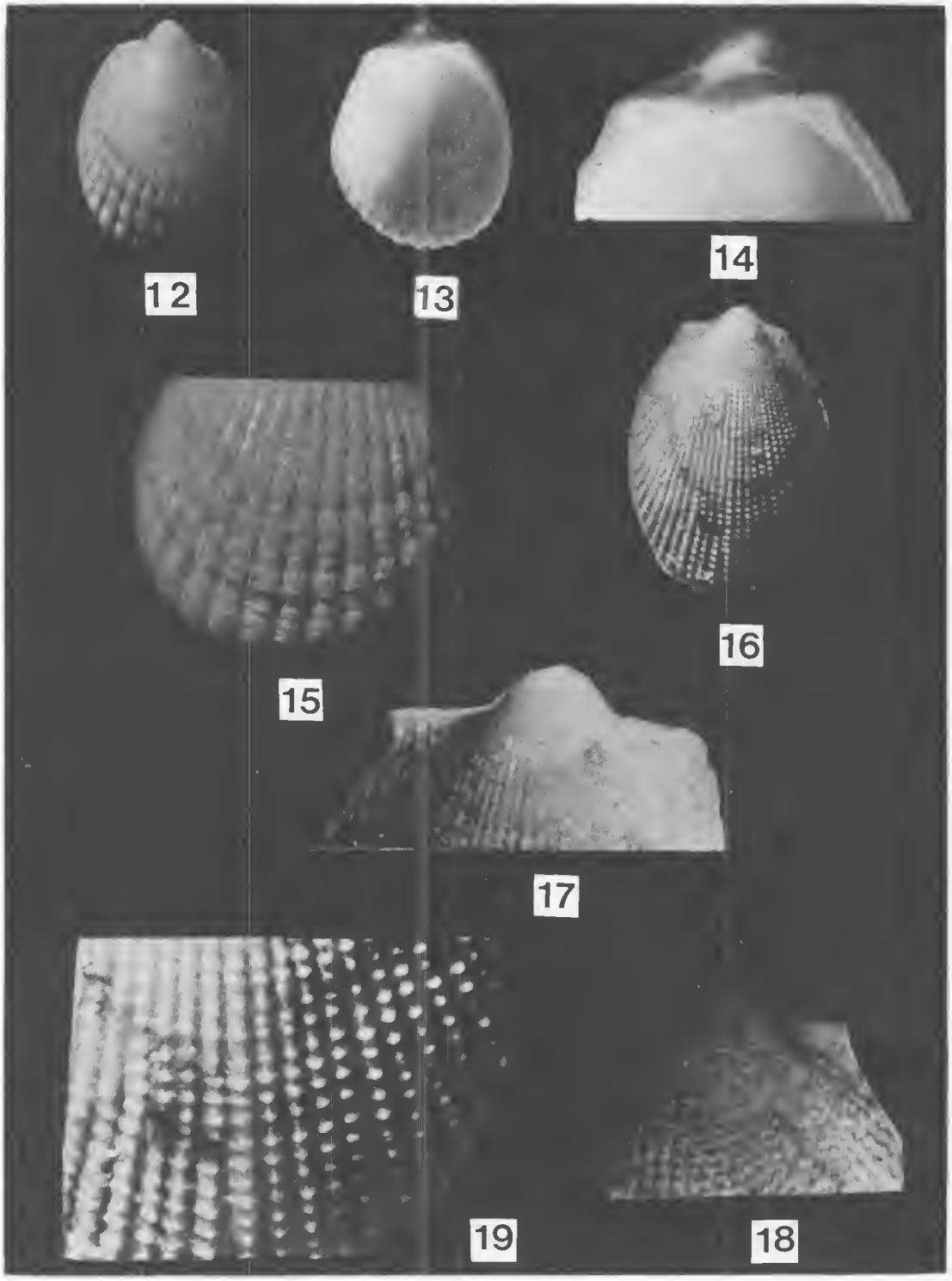
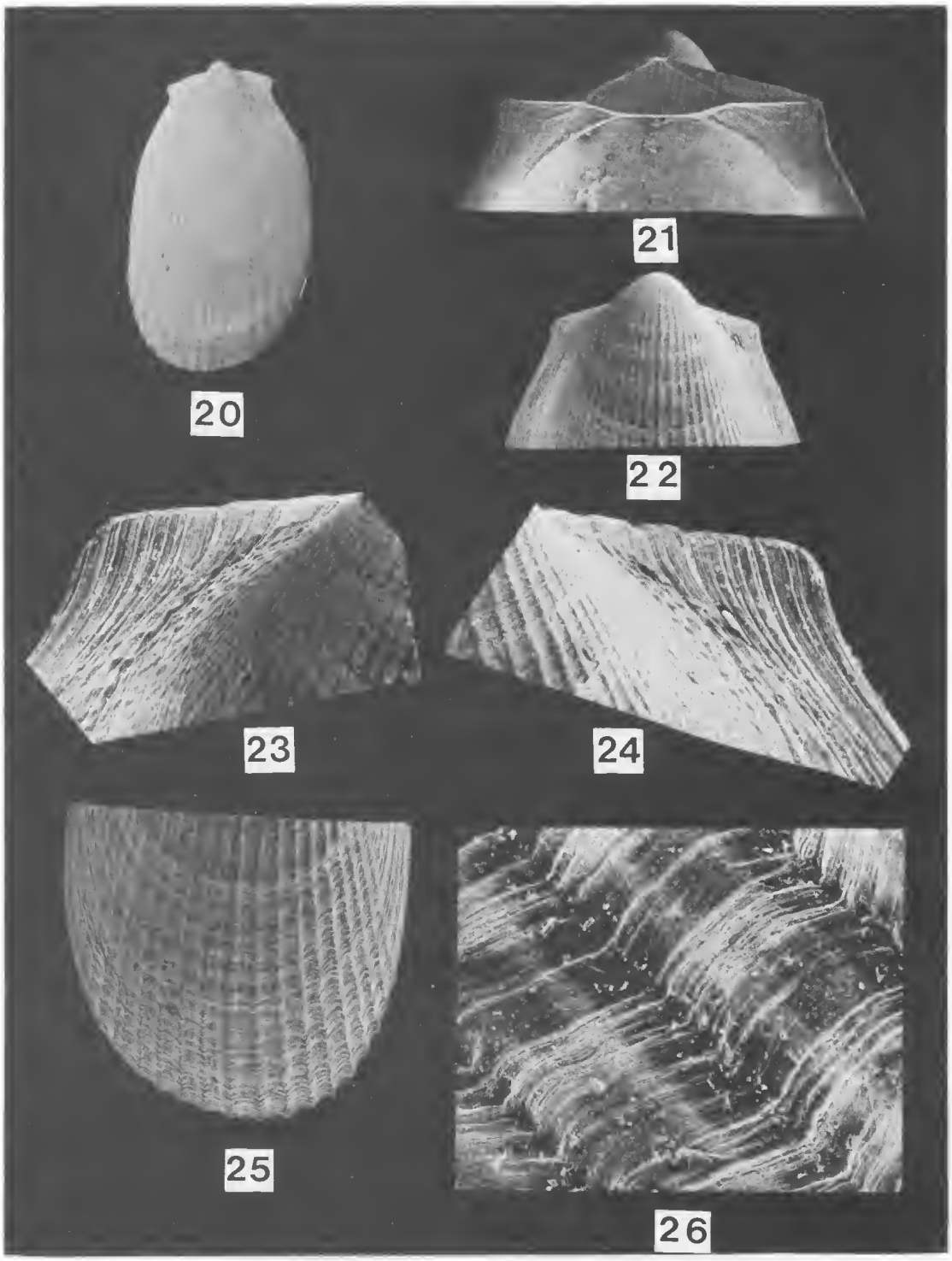


Figs 6-9. *Limatula margaritata* sp. nov., Maslin Bay; (6) Holotype, SAM P18343, RV, antero-dorsal view (x 14); (7) holotype, anterior view (x 15); (8) topotype, SAM T972-M (x 3.6); (9) ornaments, particular from holotype's postero-ventral region (x 44).
Figs 10-11. *Limatula ludbrookae* sp. nov.; SAM T972-D, Aldinga; (10) dorso-ventral view (x 6); (11) ornaments, particular from ventral region (x 16.2).



Figs 12-15. *Limea (Gemellima) austrina* Tate, holotype of *Limatula subnodulosa* Tate, SAM T1799, Muddy Creek; (12) dorsal view (x 8); (13) interior view (x 8); (14) hinge and cardinal area (x 17); (15) ornaments, particular from dorsoventral region (x 20 c).

Figs 16-19. *Limatula crebresquamata* Tate, holotype, SAM T978-A, "Spring Creek"; (16) dorsal view (x 3.75); (17) umbo and anterior auricle (x 11.25); (18) posterior auricle (x 11.25); (19) ornaments, particular from dorso-ventral region (x 15).



Figs 20-26. *Limatula strangei* (Sowerby); (20) type figured by Cotton & Godfrey, SAM 15145, Hardwicke Bay, South Australia, LV (x 1.2); (21) hinge and cardinal area, specimen SAM D9431-B (Coll. Verco) (x 15); (22) dorso-umbonal region, SAM D15146-A (x 10); (23) posterior auricle, SAM D15146-A (x 40); (24) anterior auricle, SAM D15146-A (x 40); (25) ventral region, SAM D15146-A (x 10); (26) ornaments, particular from the dorsoventral region, SAM D15146-A (x 80).

TABLE 1

Comparative synopsis of morphological characteristics

Species	Outline	Inflation	Radial Interspaces	Radial Ribs	Concentric Ornaments	Radial Ribs on Anterior and Posterior Region	Ears Triangular Subequal	Age
Limatula margaritata sp. nov.	oval, rather short	more inflated	shallow narrower, ⌣-shaped, wider to the anterior and posterior	40 broad, triangular, beaded	fine, roundish costellae separated by grooves	fading but still perceptible	longer, narrower with protruding ends and fine concentric costellae	LATE EOCENE
Limatula crebresquamata Tate	oval to subtrigonal, shorter	very inflated	deep, narrower, ⌄-shaped slightly broader	44 very high, thin, in some places dichotomous bearing chevron shaped scales	growth lines and scales	well marked	long and narrow with protruding ends and concentric costellae	LATE OLIGOCENE-EARLY MIOCENE
Limatula jeffreysiana Tate	oval, high	less inflated	broader, shallow, concave to flattened, wider to the anterior and posterior	34-37 rather fine, triangular more spiny to the ventral region	very fine growth lines with broadly interspaced costellae	fading but from perceptible to more marked	longer, narrower with protruding ends and concentric costellae	EARLY-MIDDLE MIOCENE
Limatula ludbrookae sp. nov.	oval, rather short	more inflated	narrower, deep, ⌣-shaped, wider to the anterior and posterior	30 broad, triangular with rare very short and small spines on ventral	flat, fine costellae separated by shallow, broad grooves	more fading	shorter, narrow, with protruding ends and very fine growth lines	LATE PLIOCENE

quoted by Dennant & Kitson (1903) are here omitted because specimens from those localities were not available for checking.

Stratigraphic range. As known at present, Early to Middle Miocene (Quilty 1966; Ludbrook 1973).

Limatula ludbrookae sp. nov.

FIGS 1, 10-11, 27-35

Derivation of name. From Nelly Hooper Ludbrook of Adelaide for her devotion to Palaeontology.

Holotype. SAM P18360, figs 27-28.

Type-formation. Dry Creek Sands (Late Pliocene, Yatalan).

Type-locality. Salisbury Bore, 1942, hd. Munno Para, sec. 4000, at 100 m depth.

Material. 10 specimens from Salisbury Bore (6 LV + 3 RV + 1 VV); 1 LV specimen from Tate Collection (SAM T872-D). Two broken specimens from Abattoirs Bore.

Description. Shell oval, auriculated, very high and narrow, very inflated, sub-inequilateral; umbones with small protruding and prosocline beaks. Non-gaping margins: anterodorsal and posterodorsal represented by two subequal auricles, longer than high; anterior subelliptical very long; posterior very long, slightly more elliptical; ventral very elliptical. Margin connections: anterior-anterodorsal and posterior-posterodorsal angular and concave; others imperceptible.

Longitudinal shell section subtrapezoidal, very convex. Regions: anterior and posterior very declivous, subconvex; dorsoventral convex, more gently declivous. Connections between the regions imperceptible. Cardinal area broad, longer than high, horizontally striated; resilifer triangular, broad, rather deep with curved margins. Hinge edentulous. Inner septum below the cardinal plate. Interior with marked median rib and fine regular striae. Monomyarian, posterior scar at high middle posterior position near to the median rib. Pallial line marked. Commissure region smooth except on ventral margin where it is highly crenulated.

Ornament. 29 triangular radial costae with broader trapezoidal interspaces. From the beak to the ventral margin a marked broad median sulcus. Fine concentric growth lines; fine growth rugae in adult-senile stage. At costaline/ruga intersections short spines. On the anterior and posterior region, the costae fade abruptly and the growth lines and rugae predominate. Auricles with concentric growth lines and rugae.

Observations. This form was initially mistaken by Tate for *L. jeffreysiana*. The juvenile SAM T972-D from Aldinga is broken at the umbo and is the only specimen available from outcrop. A search in the uncatalogued part of Tate's collection still kept in the Department of Geology and Mineralogy of the University of Adelaide, led to the discovery of 8 juveniles, 1 adult, and 1 senile specimen from Salisbury Bore. These specimens corroborate the distinction of this form from *L. jeffreysiana* on the basis of rib and interspace shape and shell geometry. The senile was chosen as holotype because of its perfect preservation. The specimen of *L. jeffreysiana* (Tate) reported by Reynolds (1953) in the Pliocene of Aldinga should be more probably referred to *L. ludbrookae*.

Distribution. St Vincent Basin; Aldinga Bay, Hallett Cove Sandstone; Abattoirs Bore, Salisbury Bore (type), Dry Creek Sands.

Stratigraphic range. Yatalan (Late Pliocene).

Limatula crebresquamata (Tate 1899)

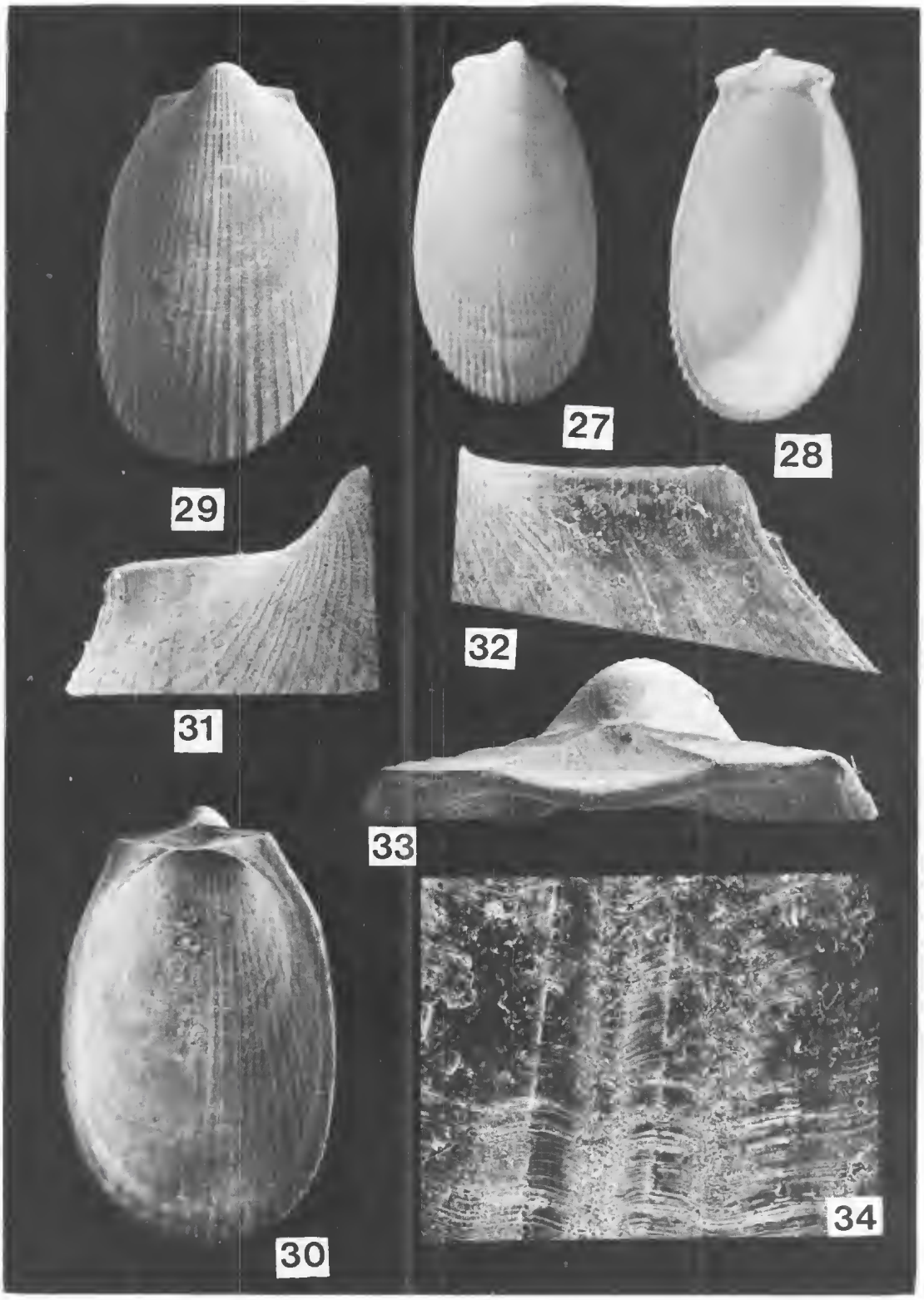
FIGS 16-19

1899 *Lima* (*Limatula crebresquamata* Tate, p. 274.

Material. Three specimens borne on the tablet SAM T978 (3 LV): T978-A, the holotype broken and glued up on the antero-ventral region; T978-B, well preserved, juvenile; T978-C, broken, with the dorsal region, the umbo and the auricles missing.

Description. Like the above described species, but differs by a shorter oval to subtrigonal outline, more inflation, and the occurrence of ribs on the anterior and posterior regions. Cardinal area narrow, longer than high, horizontally striated; resilifer triangular, concave, rather deep. Hinge edentulous. Interior with marked radial ribs and narrower interspaces. Pallial line and adductor scar imperceptible. Commis-

Figs 27-34. *L. ludbrookae* sp. nov., Salisbury Bore; (27) Holotype (SAM P18360) dorsal view (x 2.2); (28) holotype, interior (x 2.2); (29) paratype (SAM P18360) A/LV, dorsal view (x 9); (30) Paratype (SAM P18360B) LV, interior view (x 9); (31) paratype (SAM P18360A) anterior auricle (x 35); (32) paratype A, posterior auricle (x 37); (33) paratype B, cardinal area (x 27); (34) paratype A, particular median sulcus (x 72).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sure region smooth, except the ventral heavily crenulated.

Ornament. 44 ribs, very high, thin, in some places dichotomous, bearing wide, thick, chevron-shaped concentric scales, separated by regular rather broad concentric furrows. Radial interspaces U-shaped, narrower in the dorso-ventral region, increasing in width to the anterior and posterior auricles.

Observations. The morphology of this form agrees with the diagnosis of *Limatula* Wood of Cox & Hertlein (1969, p. N389), except in the strong radial ribbing of the anterior and posterior regions. The median sulcus is obscured by the heavy costae and squamae, revealed only by the inner median sulcus. An inner ridge just below the cardinal area may represent an embryonic septum as in *L. ludbrookae.*

Localities. "Spring Creek" (Tate 1899), Bird Rock, Torquay (Fleming, in litt. 1974).

Stratigraphic range. Late Oligocene-?Early Miocene (Janjukian-Longfordian).

Observations. Neither the holotype nor paratypes were figured.

GENUS *Limea* Bronn, 1831.

SUBGENUS *Gemellima* Iredale, 1929.

Limea (Gemellima) austrina Tate, 1887

FIGS 12-15, 36-41

1887 *Limea austrina* Tate, p. 73, pl. 4, fig. 7. 1899 *Limatula subnodulosa* Tate, p. 273. 1907 *Limaea austrina*-Verco, p. 315. 1929 *Gemellima austrina*—Iredale, p. 166. 1938 *Gemellima austrina* —Cotton & Godfrey, p. 107, fig. 93.

Material. 1 specimen (LV) (SAM T1799), the holotype of *L. nodulosa* Tate; several hundred specimens (SAM Lot T17).

Description. Shell small, thick, trigonal, slightly higher than long, slightly inequilateral, very inflated; umbo inflated with central orthogyrate beaks protruding a little. Margins: anterior subelliptical; posterior elliptical, both winged; ventral very elliptical. Margin connections: broadly angular; the antero-ventral rounded. Ears triangular, very narrow, and subequal.

Longitudinal shell section very convex. Regions: anterior and posterior very steep; dorsal declivous; ventral very steep. Cardinal area longer than high; resilifer triangular broad, concave, and shallow; hinge with very fine vertical teeth; monomyarian with orbicular adductor scar high in the posterior region; pallial line imperceptible or not easily distinguishable from other concentric grooves in the shell interior; commissure region heavily crenulated.

Ornament. Outer: 25 radial large massive protruding ribs with narrower deep U-shaped interspaces; fine regularly interspaced concentric costellae; rib-costellae intersections producing short subtriangular spines; irregularly interspaced broad concentric constrictions. Ears bearing only concentric costellae. *Inner:* fine radial grooves corresponding to the outer ribs; irregular concentric grooves corresponding to the outer concentric constrictions.

Observations. The rediscovered holotype of *Limatula subnodulosa* Tate, 1899 is just a worn and polished fossil specimen of *Limea (Gemellima) austrina* Tate, 1887.

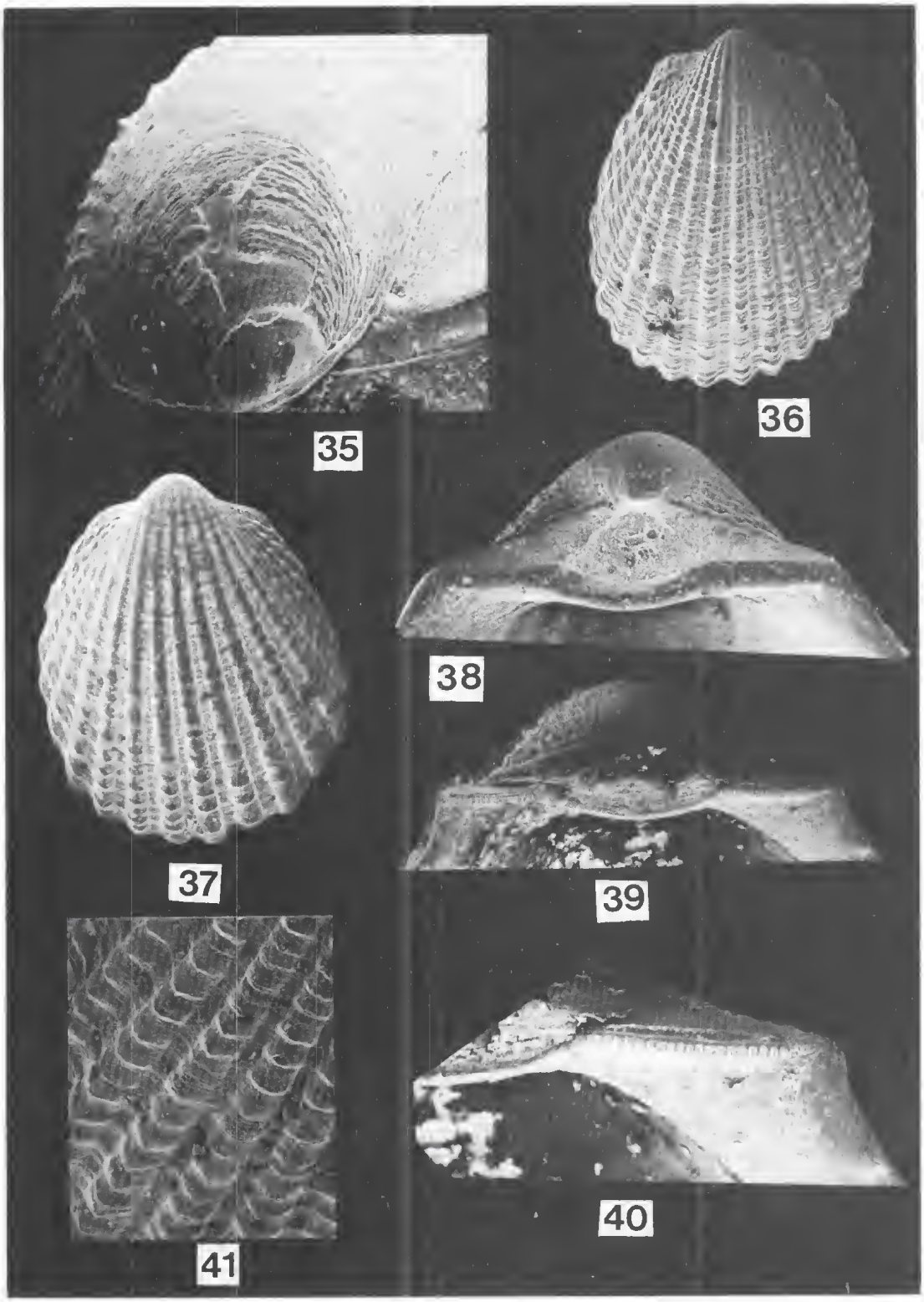
Investigations on several hundred specimens of a sample from Investigator Strait, 36.6 m depth, showed that as soon as the disarticulated valves lose the ligamentary organic matter, their hinge, composed of very fine vertical teeth, is abraded very easily; if the abrasion go further, the crenulated commissure region can be practically smoothed out and the spines on the ribs reduced to blunt nodules or worn out too.

This can explain Tate's erroneous determination. Instituting *Limatula subnodulosa* he remarked that the shell displays *Limea* characteristics, and, although he suspected it was reworked, he did not consider the possibility that it could be actually a worn specimen of *Limea. Limea (Gemellima) austrina* is the type species of *Gemellima* Iredale, considered by Newell (1969) a subgenus of *Limea* Bronn.

Study of the above-mentioned sample indicated two main morphs connected by transitional forms. One is shorter and longer, less inflated, with broader interspaces between ribs. The other is higher and narrower, more inflated, with narrower interspaces (*subnodulosa* type).

Environmental observations. Limea (Gemellima) anstrina was dredged in S.A. waters at 14.6-366.0 m, alive from 27.45-40.3 m; the optimum depth for populations seems to be 36.6 m (Verco 1907).

Fig. 35. *L. ludbrookae* sp. nov. paratype B, prodissoconch (x 135).
Figs 36-41. *Limea (Gemellima) austrina* Tate, Investigator Strait. (36) LV, juvenile, dorsal view (x 9.5); (37) LV, worn juvenile, dorsal view (x 9.5); (38) worn hinge (x 18); (39) hinge (x 18); (40) particular posterior hinge (x 36); (41) particular dorso-ventral ornaments (x 18).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Distribution. Spencer Gulf and Gulf St Vincent, recent deposits; Muddy Creek, Grange Burn Coquina; Otway Basin; Limestone Creek, W. Victoria (*fide* Dennant).

Stratigraphic range. Early Pliocene (Kalimnan)-Holocene.

Acknowledgments

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This paper is dedicated to Mr B. C. Dawes, Ashland Oil, Canada, remembering our fruitful and stimulating discussions.

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Appendix

Stratigraphical observations on Tortachilla Limestone Reynolds, 1953 (Lower Aldingan Stage).

A study of the lithostratigraphy of the fossiliferous Eocene beds at Maslin Bay will be presented elsewhere. Meanwhile a summary is necessary for adequate stratigraphic characterization of *Limatula* and other molluscs.

The Tortachilla Limestone (Reynolds 1953) considered by Ludbrook & Lindsay (1966) and Ludbrook (1973) to be the lowest rock unit in the stratotype for the Aldingan stage (Late Eocene), displays erosional unconformities. The major unconformity (Jenkins 1974, figs 1, 3) separating the lower member (Polyzoal Limestone Member of Reynolds) from the upper one (Blanche Point Glauconitic Limestone Member of Reynolds), is a deeply pitted erosional surface on the topmost limestone in the Polyzoal Limestone. The abundant subvertical pits are filled by the glauconitic sands, in places cemented by sparite, of the Blanche Point Glauconitic Limestone Member. By analogy with the studies of Jaanusson (1961 p. 232 *et seq.*), Krawiec (1971), pp. 128-31), and chiefly by Guilcher (1953) and Wentworth (1939) this unconformity could be interpreted as produced by sub-aerial dissolution of the emergent limestone, i.e. karst. The constant widespread occurrence of the pits can be explained in the negligible slope of the formation at the time of emergence, thus preventing the accumulation of beach deposits thick enough to protect the limestone from the action of erosive and dissolutive agents.

The discovery of this karst surface leads to a stratigraphic revision of the Tortachilla Limestone, restricting the formation to its previous lower member and referring the Glauconitic Limestone Member to the Blanche Point Transitional Marls, to which it belongs in a new episode of sedimentation. The record of this karst surface is the evidence of a lacuna that covered a span of time still unascertainable but longer, however, than has been considered until now.

A precise correlation of the Tortachilla Limestone in terms of planktonic foraminiferal zone is not yet possible.

S. Shafik (pers. comm. 1974) stated "the ranges of the few calcareous nannofossils extracted from Tortachilla Limestone are confined mainly to the Middle to Late Eocene".

McGowran & Lindsay (pers. comm. 1974-5) and Ludbrook (1973) support a probable early Late Eocene age for this formation. Lindsay (1969) considered the undifferentiated deposits of Tortachilla Limestone (or its equivalent) and Blanche Point Transitional Marls, in the Adelaide Plains Sub-basin to be early in the Late Eocene.

At present, the only two biostratigraphic controls on the older part of the section at Maslin Bay are:

— the microfloral asemblage occurring in North Maslin Sands and belonging to the *Proteacidites confragosus* zone, earliest Middle Eocene in age McGowran, Harris, & Lindsay 1970), but possibly latest Early Eocene (McGowran pers. comm 1975).

— The *Hanzkenina primitiva* sub-zone occurring in the Transitional Marls at Maslin Bay, southward of "Uncle Tom's Cabin", 80-115 cm above the described karst surface and estimated to be Mid-Late Eocene in age (McGowran, Lindsay & Harris 1971).